

# Automated Painting for Aerospace, Challenges, Newer Technologies and Lessons Learned

Steven Allen Becroft  
Encore Automation

## ABSTRACT

Many Aerospace Manufacturers desire to automate their painting processes to improve quality, reduce coating and other materials usage, and reduce labor content. Automated Painting Systems have been developed for a number of industries, but are less common in Aerospace for a number of reasons, including 1) very large objects to paint with complex surfaces, 2) parts to be painted which are not located accurately or consistently, and 3) a (relatively) small number of parts to paint although often a very large variety of different parts. In developing and implementing automated painting systems, these challenges need to be overcome in robust and cost effective ways, and technologies have been developed and are being enhanced to deal with these challenges. This paper will address some of the most important technologies which are being used to facilitate implementation of automated painting systems.

The robotic systems to paint the very large objects such as wings, fuselages, stabilizers, or entire aircraft are more complicated manipulators with a variety of mechanical axes and the more complicated programming and motion control systems that go with them. In a typical implementation, a six axis painting robot is manipulated using a rail, a rotating column, and a z-lift. Programming of these multi-axis manipulators and robots is difficult to do by using conventional teach pendant techniques, but can be done with offline programming software. Vision systems and software are used to locate the parts in space and to apply offsets to the programmed motions.

Vision systems and software can also be used to automate the programming of aircraft component parts to provide the capability to paint 90%+ of the surfaces for a large variety of parts. An image of each part is taken, and key parameters are determined and input into a software algorithm which will determine the motion program for painting the part. In this way, thousands of different parts can be automatically painted without the programming of individual paths for each unique part.

Most aerospace painting is typically done with air atomized or high volume low pressure electrostatic guns. Electrostatic rotary atomizers have proven to be advantageous in automated painting systems in optimizing transfer efficiency, appearance, and in reducing paint defects. Grounding of the parts is important and control of the painting parameters is critical to optimizing achieving the best results.

This paper will describe in detail the technical challenges, and some of the techniques and technologies used to accomplish these processes, and what lessons were learned during their implementation.

**CITATION:** Becroft, S., "Automated Painting for Aerospace, Challenges, Newer Technologies and Lessons Learned," *SAE Int. J. Aerosp.* 5(1):2012, doi:10.4271/2012-01-1855.

## INTRODUCTION

Two of the more common aerospace painting applications are the following: 1) painting large aircraft or large component parts, or 2) painting large varieties of smaller component parts. In these two different areas of applications there are a number of technological hurdles and challenges that make these applications difficult to automate. Jennerjohn describes these challenges in his paper [1] and Milojevic [2] adds more background and also describes some advancements in approach and technology that one company

has made to address the Aerospace industry. While these technological challenges are difficult, robotics, coating, vision, and control technologies have advanced over the recent decades to make these automation applications more feasible and cost effective. This paper will address these technological hurdles and challenges, and describe some of the enabling technologies and approaches which have helped provide solutions to them. Two proposed solutions for Aerospace Painting Systems are then described.

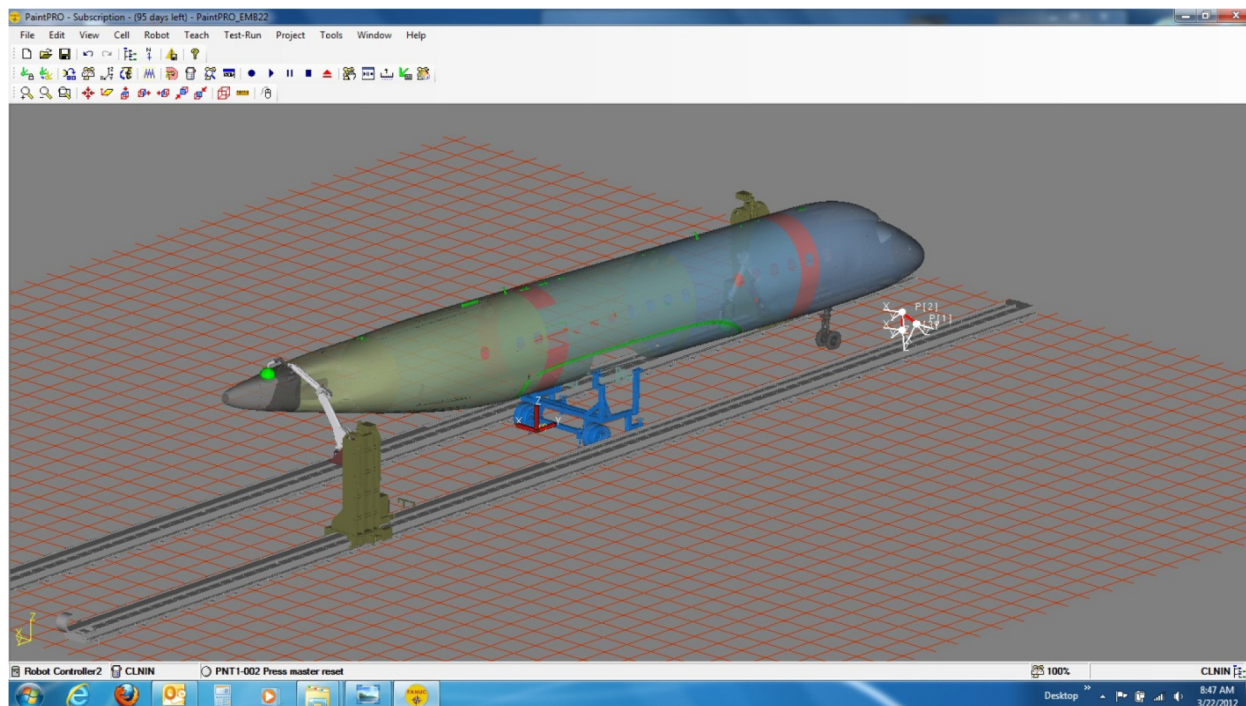


*Figure A. Screen Shot of Offline Programming Software*

## DEALING WITH SIZE

Aircraft Painting operations often handle larger and complex parts, either individually or assembled into portions or a complete aircraft, and are difficult to paint. To be able to provide a uniform, high quality paint finish, the paint spray applicator needs to be maintained at a certain angle and distance from the surface of the part to be painted. Simulation tools are used (as shown in [Figure A](#)) to help determine and to validate different manipulator configurations which will provide the ability to move a spray applicator along a surface to achieve the desirable paint finish.

Often, the best and most cost effective solution is to use a 6 axis robot carried by either 1 or 2 or 3 additional axis movers in the form of rails, vertical lifts, or rotation axes. The axes above and beyond the 6 axis robot axes are often called Auxiliary Axes. A typical configuration is shown in [Figure B](#), where a six axis robot is carried by a carriage which vertically moves along a rotating column that itself travels along a long rail axis which optionally can travel along several rail axes. This is a total of 9 (or optionally 10) axes, and in many cases two of these configured manipulators can provide the flexibility and range to move an applicator along the surface of a large aircraft part, or optionally along the surface of an entire aircraft. Developing the designs, models, motion programs, with painting parameters and part location offsets, is a particularly difficult challenge, but existing products and technologies, extended using available design, simulation, and programming tools, can provide for the functionality to implement these solutions.



*Figure B. Typical Robot/Lift/Rail Configuration*

## PROCESS AND MOTION CONTROL

It is extremely important to provide for consistent and responsive application control, and to do that the control and motion systems, actuators and sensors must be installed as close to their point of use as possible. In this case utilities such as electrical power and compressed air must be conveyed to these control elements without degradation of their capability. Decisions must be made as to where the paint

and solvent supply for the automated system is to be located. Pumps and tanks can be located in a mix room nearby the automation cell, and long hoses can convey the paints and solvents to the applicator. Alternatively, the paint and solvent containers can be placed at or near the applicator, and refilled as required. These tradeoffs on paint materials, utilities, control devices, sensors, etc., need to be analyzed in a cost/benefit analysis to determine the best solution for each automation implementation.

In addition to high performance control and motion systems, the manipulators themselves must be manufactured to exacting tolerances, and higher resolution sensors on the drive elements are used to monitor movement and location of the various axes of the manipulator. In the end, accuracy of the manipulator's location, as well as its movement, can be corrected to some extent using the vision systems which are used to locate the part (described further on in the paper).

Care must be taken to insure that the part fixtures are optimal for automated painting. The fixtures need to be supportive such that the part location variability in the fixture is minimized. This is done by care in the design of the fixture tooling and the selection of which, and how many, portions of the part are supported by the tooling. This support tooling needs to minimize the amount of surface which is prevented access to painting. The tooling can also act as ground sources which attract and collect the sprayed paint, impacting the transfer efficiency of the process and the finish quality. Using non-conductive material for fixtures, as well as minimizing the size and weight of this tooling will minimize this paint overspray problem.

## SIMULATION AND MOTION PROGRAMMING

The programs used by the manipulator motion control system to move the applicator are best taught using an offline programming system (OPS), since programming using a teach pendant or other manual means is not feasible for large parts and manipulators with limited visual access. The OPS consists of a special software system which uses the following 1) a CAD model of a part to be painted, the manipulator and applicator, as well as the workspace and all of their constraints, 2) an assumption of the actual physical relationship of the part to the manipulator base, 3) a motion algorithm for the manipulator which describes how the motion is to be controlled, and 4) a model of the spray applicator and application process with assumptions for the fan pattern, target distance, paint flow rate, and transfer efficiency. The OPS is used to develop the initial motion programs for the manipulator which can then be offset by part location information (discussed later), and then tested in the actual workplace using a sample part. The OPS product used is often that of the manufacturer of the 6 axis robot, and extensions are programmed in to account for the Auxiliary Axes which have been added. To make the motion mathematics feasible, the Auxiliary Axis positions are first

programmed, then the 6 axis robot position is determined in order to locate the applicator at the right location and orientation, all of this to determine the programmed position. A motion step consists of moving all of the axes to reach the next programmed position, and a motion program is a collection of these motion steps along with associated parameters which determine the application approach. An example of a motion program in the form of a simulation created by an OPS is shown in [Figure C](#) (hyperlinked). In all cases there will need to be adjustments to this offline program to refine applicator position and associated data to obtain the desired paint finish result (due to model inaccuracies, environmental effects, and process effects), and often several or more refinements will be needed to obtain acceptable quality.

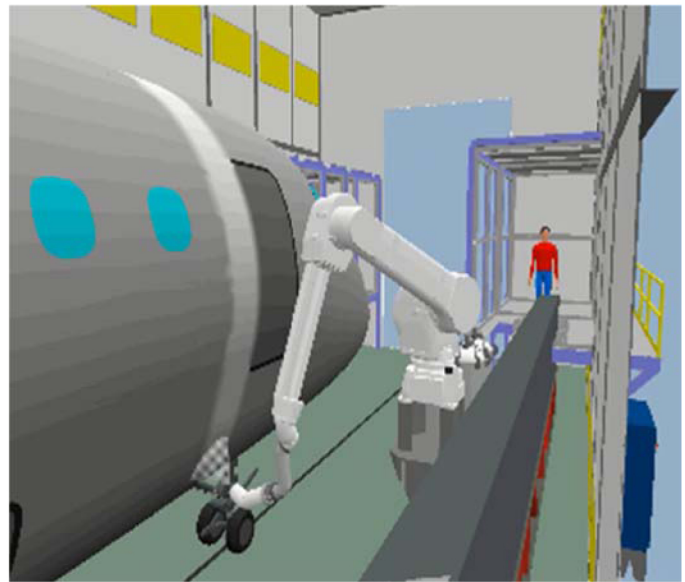


*Figure C. Jet Aircraft Robotic Painting Simulation*

## LOCATING THE PART

Large Parts are difficult to locate accurately, and the more accurately they have to be located the more it hampers the production process. Part location tolerances include part to fixture tolerances, fixture to fixture (or fixture adjustment, when fixtures are adjustable) tolerances, fixture location tolerances, as well as the inherent manipulator location tolerances. Part Location Systems (PLS) are mathematical programs that use sensors to locate multiple targets on the part to determine its location, and offset the programs for the part location tolerances. This part location must be done every time a new part is placed in the painting cell. These systems, depending on the sensor technology used, have their own hurdles that must be overcome to make them effective. Targets need to be carefully selected to optimize the accuracy and robustness of the PLS. It is best to have targets that are the maximum distance apart in as many of the Cartesian